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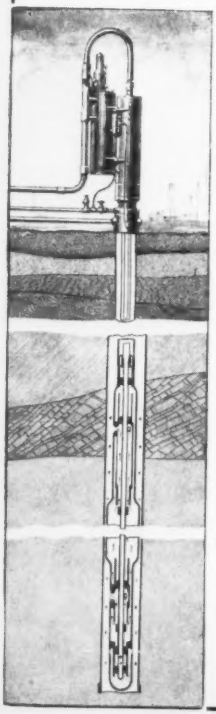

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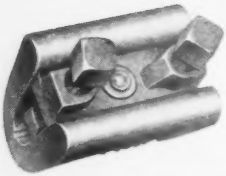

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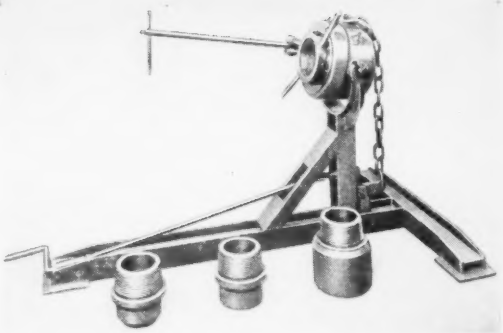

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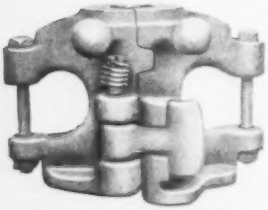

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NEW PHYSICAL METHODS IN THE PETROLEUM INDUSTRY

By K. G. BRUMMAGE, P. W. COOKE AND R. R. GORDON*

INTRODUCTION

THE application of physical methods in the petroleum industry, as in many other industries, is now so widespread that in order to deal adequately (within the limits set by a paper of this kind), with any portion of the subject and to prevent the paper becoming little more than a mere catalogue of applications, some fairly severe selection of subject matter is essential. The selection which has been made has been governed primarily by the word "new", whose meaning in turn has been restricted to new as applied to industry.

This explanation is felt to be necessary since the fundamentals of the methods to be described—particularly of the spectroscopic methods—are by no means new. It is the application of these fundamental principles to specific industrial processes and objects, which is the new feature.

We have therefore chosen as our subject matter the developments which have recently taken place in three main spheres: (1) Spectroscopic analysis by both absorption and emission methods (sections are included on Raman spectra and on the Mass Spectrometer); (2) Electron diffraction and its application to lubrication investigations; and (3) X-ray diffraction and its uses in analysis, in determination of crystal size and structure, in investigation of phase transitions and the like.

It is hoped that in each case, sufficient explanation is provided of the underlying principles, so that the non-expert

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may acquire a grasp of the basic method, which whilst being free from the encumbrance of working detail, will be basically sound.

SPECTROSCOPIC ANALYSIS

Origin of Spectra

The fact that radiation is of a wave nature and that the different wavelengths composing it may be separated from one another by various means, are matters of common knowledge. One of the commonest methods is by the action of a prism and it is with this method and its applications that we shall deal mainly in this section. The spectra which are observed by means of a prism fall into two main divisions—emission and absorption, both of which have their uses in the petroleum industry.

Emission spectral wavelengths (or lines as they appear when using a spectrograph) are due to changes in the electronic configuration of the atom. By supplying sufficient energy to the atom, electrons are caused to move from their normal stable energy levels with respect to the atomic nucleus and are raised to higher unstable energy levels. On returning to their former lower energy levels, the electrons re-radiate the absorbed energy and an emission line results whose wavelength or frequency is related to the difference in energy contents of the two levels by Planck's relation:

$$E = E_1 - E_2 = h\nu$$

where $E_1 - E_2 = E$ = Energy difference (ergs)

h = Planck's Constant = $6{\cdot}62 \times 10^{-27}$ erg. sec.

ν = Frequency (vibrations/sec).

This involves the quantum theory concept that radiation consists of a series of packets, or quanta, of energy, the quantum having an energy content which is proportional to the vibration frequency. The processes of both absorption and re-emission of energy are discontinuous. That is to say, since the electron can only move from level A to level B or level C and cannot rest at intermediate points, it must absorb and re-emit appropriate quanta. It can neither absorb nor re-emit a fraction of a quantum and consequently until the energy content of the quantum of the exciting radiation reaches a certain minimum, no absorption or re-emission can take place. The fine structure observed in certain cases is explained by the fact that in relatively complicated atoms many of the possible energy levels are close together so that many radiations are emitted or absorbed in a given band of frequencies. If these cannot be resolved by the spectroscope, we get a rather broad band whose fine structure can be examined only under greater resolution.

With molecules the position is more complicated in that the energy may be changed in two additional ways:

(a) By causing the atoms to vibrate as a whole with respect to each other; and

(b) By causing the whole molecule to rotate about some space fixed axes.

The order of energy change or quantum involved in the vibrational change is only about one-tenth to one-hundredth of the electronic energy change, and the rotational quantum is again roughly one-tenth to one-hundredth that of the vibrational quantum. From Planck's relationship these different orders of energy will cause the corresponding frequencies to be spaced widely in the spectrum. For example electronic changes occur in the ultra-violet region 2000–3500 Ångströms (1 Ångström = 10^{-8}cm), vibrational changes occur in the near infra-red 1μ—30μ 1μ = 10^{-4} cm. = 10,000 Ångströms) and rotational

changes in the far infra-red region 50–150μ.

These various methods by which a molecule may change its energy content and the various regions of the spectrum in which the effects may be observed, have been used to form the bases of methods of hydrocarbon analysis.

All hydrocarbons absorb in the infra-red and in the far ultra-violet (below 2000 Å) but the latter region at present involves techniques which are very difficult even for the research laboratory and out of the question for industrial work. On the other hand—and this fact is extremely useful for analytical purposes—aromatic compounds absorb in the near ultra-violet (2500-3000 Å) in which range saturated paraffins and naphthenes show no absorption.

The valency electrons mainly responsible for absorption in the near ultra-violet by hydrocarbons, are those loosely bound wandering electrons which are responsible for the carbon/carbon ring linkages. These electrons are easily excited to higher energy levels with relatively low energy. The outer electrons require higher energy and hence absorb in the far (short wave) ultra-violet. It follows from this that the effects of changes in the side chains

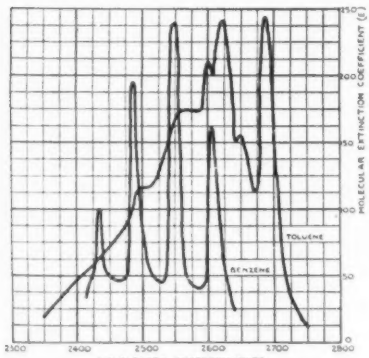

Fig. 1.—Ultra-violet Absorption Spectra of Benzene and Toluene

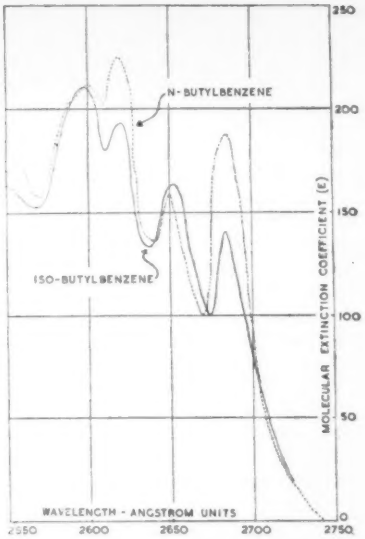

Fig. 2.—Ultra-violet Absorption Spectra of n and isobutyl Benzene

attached to a benzene nucleus for example will have less effect on the observed spectrum than changes in the positions in which these side chains are attached to the nucleus. This sets a limit to the ultra-violet spectroscopic method where the molecular changes are confined entirely to the side chains; for instance, it is almost impossible to differentiate between *n* and *iso*butyl-benzene but where there is some change also in the aromatic nucleus, e.g., benzene, toluene, xylene—the differences are large enough to provide the basis of an analytical method. The benzene and toluene ultra-violet absorption spectra are shown in Fig. 1 and those of *n* and *iso*butyl-benzene in Fig. 2.

In the infra-red, it is the masses of the atoms, the interatomic binding forces and molecular symmetry which determine the absorption bands observed and except for optical isomers therefore, no two hydrocarbons should show the same infra-red absorption spectrum. A

limit to the "fingerprinting" of hydrocarbons in this way however, may be set by the increasing complication of the spectra due to the appearance of overtones of the fundamental frequencies, and to the additional factor of combination frequency bands arising from two or more fundamentals. Thus for the more complex molecules, the chances of compounds interfering with each other in spectroscopic analysis, increase greatly. The limit has not yet been reached, however, nor is it in sight up to C_{10} compounds. In order to limit the complexity of both the resultant spectra and the computations involved, it is essential to limit the number of components in a mixture to be analysed, to a maximum of around eight. This can normally be done by straightforward distillation procedure.

The Ultra-Violet Absorption Method

So far we have been almost purely fundamental and certainly entirely qualitative in our treatment of the problem. This is insufficient for industrial application and control which requires accurate measurement; and the apparatus and techniques employed for this purpose must now be described.

Strictly quantitative methods have been developed on the basis of two laws—Beer's & Lambert's. These state:

(1) That the amount of radiation absorbed dI by an elementary column of solution is proportional to the intensity I of the incident radiation, to the length dt, and to the concentration c of absorbent in g. mol/litre.

This may be expressed mathematically.

$$dI = EIc\,dt$$

$$\int_{Ie}^{Io} \frac{dI}{I} = \int_{o}^{t} Ecdt$$

$$\text{or } \log \frac{Io}{Ie} = Ect.$$

The quantity $\log \frac{Io}{Ie}$ is defined as the optical density d and the constant E is termed the Molecular Extinction Coefficient. At a given wavelength E is the optical density of a 1 cm path of solution having a concentration of 1 g.mol/litre.

$$\text{Thus } E = \frac{d}{ct}$$

Beer's law holds well in the ultra-violet (i.e., there is a linear relationship between optical density and concentration) for hydrocarbons but fails to some extent in the lower energy region in the infra-red, largely for instrumental reasons.

(2) Lambert's Law is the simple statement that the optical density of a mixture is the sum of the optical densities of the components of the mixture—i.e., the components do *not* interfere with one another in their absorptions.

In essence then the analytical procedure is as follows:

In an *n* component mixture containing concentrations (unknown) of c_1, c_2, c_3 . . c_n of the absorbing compounds, the optical densities d_1 . . d_n are determined at each of *n* wavelengths λ_1, $\lambda_2 - \lambda_n$. The molecular extinction coefficients E_1, $E_2 - E_n$ of all the pure components must be known at each of the *n* wavelengths.

We then have a series of simultaneous equations thus:

$$\begin{bmatrix} \lambda_1 & \lambda_1 & \lambda_1 & \lambda_1 & \lambda_1 \\ d_1 = t\,E_1\,c_1 + E_2\,c_2 + E_3\,c_3 - - - E_n\,c_n \end{bmatrix}$$

$$\begin{bmatrix} \lambda_2 & \lambda_2 & \lambda_2 & \lambda_2 & \lambda_2 \\ d_2 = t\,E_1\,c_1 + E_2\,c_2 + E_3\,c_3 - - - E_n\,c_n \end{bmatrix}$$

$$\vdots \qquad \vdots \qquad \qquad \qquad \vdots$$

$$\begin{bmatrix} \lambda_n & \lambda_n & \lambda_n & \lambda_n & \lambda_n \\ d_n = t\,E_1\,c_1 + E_2\,c_2 + E_3\,c_3 - - - E_n\,c_n \end{bmatrix}$$

At this point the problem is solved in the mathematical sense—but the arithmetical computation remains to be done. One method of easing the labour involved when large numbers of samples have to be analysed, is to express the

solution to these equations in determinant form. This enables the concentrations c_1, c_2, etc., to be expressed explicitly in terms of the known coefficients $E_1 - - - E_n$ and the determined optical densities d_1, d_2, etc.

Thus in the general case we have solutions of the form

$$c_1 = A_1 d_1^{\lambda_1} + B_1 d_2^{\lambda_2} + C_1 d_3^{\lambda_3}$$

$$c_2 = A_2 d_1^{\lambda_1} + B_2 d_2^{\lambda_2} + C_2 d_3^{\lambda_3}$$

$$c_n = A_n d_1^{\lambda_1} + B_n d_2^{\lambda_2} + C_n d_3^{\lambda_3}$$

where the constants A_1 to A_n, B_1 to B_n, etc., involve only the molecular extinction coefficients and the (fixed) absorption path length.

Thus, for 2, 3, 4, etc., component mixtures we have available beforehand a system of 2, 3, 4, etc., simultaneous equations with numerical coefficients worked out to suit the particular components of the mixture and the instrument in use. It is therefore a simple matter to work out the concentrations by substitution of the appropriate experimental values of optical density at the wavelengths λ_1, λ_2 - - λ_n.

Apparatus and Technique

It will be clear that a complete analysis requires two series of measurements:

(1) That of the molecular extinction coefficients E of the pure components known to be present, at a series of wavelengths; and

(2) The measurement of optical density of the unknown mixture at the same wavelengths.

It will also be clear that these measurements are essentially the same in nature —both amount to the measurement of absorption (optical density) and wavelength, but one is measured on pure components only whilst the other is measured on each unknown mixture.

Two different types of apparatus are in common use for the ultra-violet region of the spectrum. These may be described roughly as the photographic and the photoelectric types respectively. In the first of these a quartz spectrograph is used for wavelength measurement in conjunction with a Spekker photometer, which is the device used for measuring absorption by solutions. The combination of the two instruments is shown diagrammatically in Fig. 3. The Spekker splits the beam of radiation from a 15,000-volt spark between tungsten steel electrodes, into two beams by the quartz rhombs. The upper beam passes through a cell filled with the solution to be analysed; the lower beam passes through a cell containing non-absorbing solvent. In the path of the lower beam is a variable aperture whose area is controlled by a calibrated drum. The graduations on the drum represent the logarithm of the area ratios of the

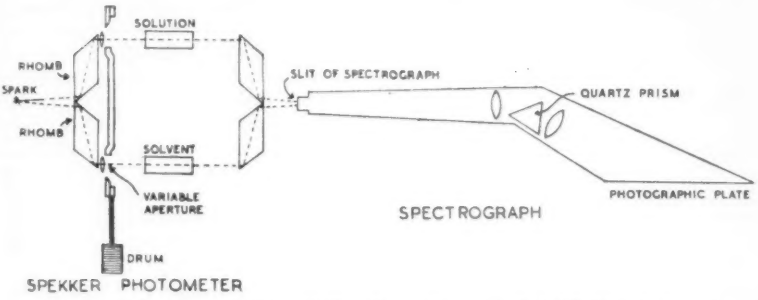

Fig. 3.—Optical layout of Hilger Medium Quartz Spectrograph and Spekker Photometer

fixed to the variable apertures—i.e., the drum is calibrated in optical densities.

The two beams are brought to a focus on the entrance slit of the spectrograph and the result is that for any one drum reading a pair of spectra is obtained and photographed. The plate holder can move vertically so that a series of such pairs of photographs may be accommodated on a single plate. If such a series is taken each photograph corresponding to a different drum reading, then at certain wavelengths it is found that the two halves of each pair show equal blackening. When this occurs it is known that the radiation has been reduced by the variable aperture to the same extent as by the solution. The drum reading at which this occurs is the required optical density.

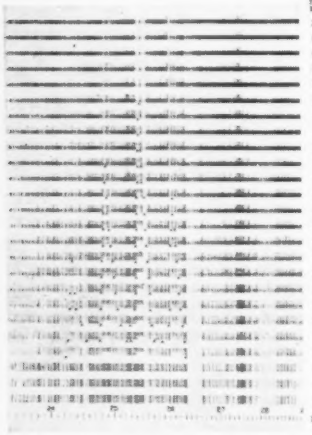

Fig. 4.—Plate exposed to determine the Molecular Extinction Coefficients of Benzene

Fig. 4 shows an example of such a plate on which the points of equality have been marked. The drum readings corresponding to these points of equality of blackening give the optical densities, and the results are finally plotted as a molecular extinction coefficient/wavelength curve (Fig. 5).

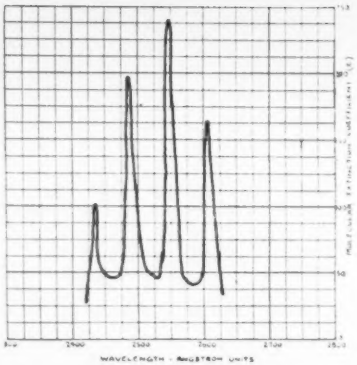

Fig. 5.—Ultra-violet Absorption of Benzene

These extinction coefficient curves are determined once and for all on the pure hydrocarbon. From these curves the key wavelengths (i.e., those wavelengths at which absorption bands occur which are characteristic of a single component) suitable for given analytical problems are selected. The above procedure is repeated for each unknown solution except that it is necessary to measure the optical densities only at the "key" wavelengths.

One correction only is necessary and this is illustrated by the bottom three pairs of spectra in Fig. 4. The need for this correction arises from the fact that it is only on rare occasions that the two beams from the Spekker are exactly equal in intensity when the variable aperture is equal to the fixed aperture, and there is neither solution nor solvent in the cells. To determine this "zero error" of the instrument a few exposures are made with the variable aperture set at a few observed positions near to the fully open setting. By comparison of these blank spectra the drum reading for equality of blackening at any wavelength may be determined. This "zero" optical density is subtracted from the optical density determined on the absorbing material.

Following the method just described four-component mixtures have been

TABLE I

Results of Analyses of Blends Containing m-Xylene, p-Xylene, o-Xylene, and Ethylbenzene.

	m-Xylene, wt. per cent		*p*-Xylene, wt. per cent		*o*-Xylene, wt. per cent		Ethylbenzene, wt. per cent	
	Actual	Observed	Actual	Observed	Actual	Observed	Actual	Observed
1	30·1	31.8±1·5	10·3	9·4±1·0	10·4	9·0±2·0	30·2	31·3±1·5
2	40·2	38·8±1·5	6·0	5·8±1·0	12·4	14·5±2·0	12·4	13·4±2·0
3	15·21	16·5±1·5	5·06	4·6±1·0	25·56	25·5±2·0	5·24	4·9±1·5
4	60·9	56·3±1·5	16·0	17·1±1·0	20·1	23·5±2·0	3·0	4·5±2·0
5	32·4	32·8±1·5	12·1	12·2±1·0	15·6	13·2±2·0	39·9	44·1±1·5
6	47·5	45·5±1·5	10·2	10·2±1·0	32·8	32·6±2·0	9·5	10·2±2·0
7	49·5	46·6±1·5	10·5	10·5±1·0	13·6	12·0±2·0	26·4	28·4±2·0
8	60·2	61·7±2·0	15·1	13·5±1·0	14·4	16·3±2·0	10·3	9·9±2·0
9	46·9	48·4±1·5	12·4	13·1±1·0	9·4	8·6±2·0	31·3	33·8±2·0
10	37·5	38·1±1·5	12·5	11·6±1·0	25·0	25·4±2·0	25·0	24·3±2·0
11	16·4	15·7±1·5	4·3	4·2±1·0	24·3	25·2±2·0	4·1	3·9±2·0
12	23·7	22·2±1·5	4·0	4·3±1·0	24·3	25·4±2·0	4·0	5·1±2·0
13	42·8	42·1±1·5	21·8	21·4±1·0	20·4	20·7±2·0	15·0	15·8±2·0

The compositions of blends 1, 2, 3, 11, 12, and 13 were not known to the spectrograph operators.

analysed with the accuracies (checked by error calculations and by comparison with synthetic mixtures) shown in Table I. Similar methods have been used successfully for the analysis of mixtures of benzene and toluene, the C_8 aromatics, for the C_9 and C_{10} aromatics and for mixtures containing conjugated dienes such as *iso*prene, piperylene and *cyclo*pentadiene.

The best example of the photoelectric type of apparatus is the Beckman Ultra-Violet Spectrophotometer produced in the United States of America. In this instrument the photographic plate is replaced by an ultra-violet sensitive photocell and instead of recording a wide range of wavelengths in a single exposure, each wavelength in turn is caused to traverse the exit slit by rotating the prism. As in the photographic method two absorption cells are required, one containing the diluted sample while the other contains diluent only. The procedure is then to select the wavelengths required for analysis of a given mixture and to measure the intensity of radiation transmitted through the sample cell and blank cell respectively. The apparatus is essentially a null instrument and in practice the photocurrent produced by the radiation transmitted through the sample is balanced against that produced by the radiation transmitted through the blank cell. The optical density, when balance is obtained, is then read directly from the potentiometer scale. The procedure thereafter is exactly as described for the photographic method.

INFRA-RED APPARATUS & TECHNIQUES

In principle infra-red spectrometers are the same as those used for the ultra-violet region of the spectrum. The experimental techniques however are quite different because:

(1). The energy available in the infra-red is much less than in the ultra-violet and the wavelength is such that it does not affect a photographic plate beyond about 12,000 Ångströms (=1·2μ). This involves a complete change in the detecting system to thermopiles or bolometers with their attendant amplifiers;

(2) Glass and quartz have only a very limited transmission for the infra-red so that rocksalt prisms must be used and mirrors must replace lenses for focusing the radiation;
(3) The wavelength range to be covered (1—15μ) is about 300 times as large as the ultra-violet range. This means that the spectrum must be traversed across the detector instead of a wide range of wavelengths being recorded in a single step;
(4) Due to the wide wavelength range to be covered the energy in the radiation varies so much that it is not possible to work with a single slit width;
(5) Since the hydrocarbons to be dealt with include both liquids and gases two forms of absorption cell must be used.

Fig. 6 shows a diagrammatic layout of an infra-red spectrometer. The radiation from the source (usually a Nernst filament which is essentially a rod composed of rare earth oxides heated electrically) is focused by surface aluminized mirrors, through the absorption cell on the entrance slit of the spectrometer. After passage through the prism it is ultimately focused on the exit slit behind which is situated the detector (thermopile or bolometer).

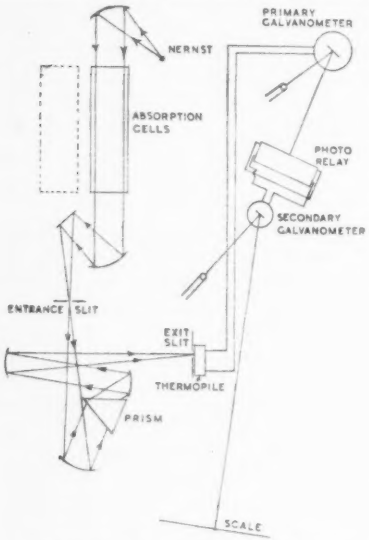

Fig. 6.—General layout and optical system of Infra-red Spectrometer

The thermopile output is taken to a sensitive primary galvanometer whose deflections are amplified by a photo-electric device to give easily readable deflections on a secondary, robust galvanometer. The instrument is maintained in a thermostatically controlled enclosure so that ambient temperature effects on the prism and electric circuits are eliminated.

In order to compensate for reflections from the end plates of the absorption cells and also for atmospheric absorption due to water and carbon dioxide or any other contaminant which may be present in the atmosphere of the laboratory, it is necessary to use a blank cell of the same dimensions as the sample cell in the case of gases. This cell is kept evacuated and at each wavelength examined the energies (measured by the deflections of the secondary galvanometer) transmitted by the blank cell and the sample cell are determined. The percentage transmission (or absorption) and hence the optical density is readily calculated from these deflections. For liquid samples, since the absorption path is so short, it is customary to use a plane rocksalt plate as the compensator.

The apparatus described is that commonly used in routine analysis but before it can be employed for this purpose it is necessary to determine certain instrumental factors. Since it is difficult to ensure that the transmissions through the blank and sample cells are exactly equal owing to the presence of "fog" which develops in time on the end plates of the sample cell, it is necessary to determine the cell zero at frequent intervals. This is done by measuring the

transmission of the two cells at a series of wavelengths when both cells are evacuated. A curve is drawn through the points so obtained and the cell zero interpolated for intermediate wavelengths.

Another instrumental factor arises from the fact that while the exit slit nominally transmits only a very narrow range of wavelengths, in actual practice owing to "scatter" within the spectrometer, the emergent energy contains a certain amount of energy of shorter wavelength. The effect of this is to give an absorption at the maximum of a peak less than the true value since the short wave radiation is not absorbed at all at this wavelength. This scattering of short wave radiation is not constant either with wavelength or with time. It also varies with the temperature and age of the Nernst filament and with the particular filament being used. It is therefore necessary to determine this factor periodically by using materials which absorb very strongly at certain wavelengths, so that in these cases the deflection given by the beam passing through the sample cell may be taken as a measure of the scattered radiation.

These two factors—cell zero and scattered radiation, must be determined if reliable analytical results are to be obtained.

Their real importance however, is much greater than that of merely maintaining quantitative accuracy in analysis. It lies in the fact that if the absorption spectra are corrected for these effects, they become very largely independent of the particular instrument on which they were obtained, and in that sense the spectra become "absolute". This means that spectra obtained on one instrument can be applied directly to analyses by other instruments of similar design: so that all pure compound calibrations, skilled personnel, and rare and costly pure materials can be centralized, and only the resulting spectra need be passed to other analytical centres for application. This is regarded as a very great advance on previous general practice, which resulted in purely qualitative absorption spectra useful only for identification and very approximate analytical purposes.

Analytical Procedure

The initial step in infra-red analysis is the same as that for the ultra-violet and consists of determining the "key" wavelengths for the pure components by examining a wide range of wavelengths. It has been found during work on gases, that Beer's Law cannot be assumed to hold in the infra-red. One of the main reasons for this has already been indicated under (4)—the need for opening up the slit at longer wavelength (low energy) regions. In fact, it is not the mere opening up of the slit, but the change in the relation of slit width to shape of absorption band, which affects the observed intensity of absorption and causes the apparent departure from Beer's Law. In general it is found that the departure is most marked in those cases where a very narrow absorption band is involved. Whether this is the only cause which in practice need be considered remains to be seen; but it seems probable that if this cause could be removed, the approximation to Beer's Law would be sufficiently close to allow us to work in terms of molecular extinction coefficients and exact simultaneous equations as in the ultra-violet. Since this cannot be done in the infra-red except in special cases, the procedure is to determine the optical densities at each "key" wavelength for a series of concentrations (or path lengths) of the pure components. In the case of gases this is easily done by using a series of gas pressures. For liquids however, a special variable path length absorption cell must be used since the normal working thickness of absorbing layer is only about 0·1 mm. Such a cell capable of giving liquid layers varying from 2mm

unstable and the atom or molecule returns to a more stable energy condition, re-radiating in the process some or all of the absorbed energy. The frequency of the energy lost as radiant energy is given by Planck's relationship. In some cases the absorbed energy is supplied in large amounts as by an arc for example and the resulting effects and their application are discussed later. In other cases the energy may be applied in a less concentrated form as for example by irradiation with monochromatic light, as in the Raman method. The great majority of molecules, after excitation by absorption, return to their original state and re-radiate energy of the same frequency as the exciting radiation. A few molecules, however, return to energy levels different from the original and in consequence re-radiate energy of frequency different from the exciting radiation. If a sample of liquid for example is irradiated with light from a mercury arc lamp and the light scattered at right angles to the direction of the incident beam is photographed through a spectrograph then the resulting plate will show not only a strong line corresponding to the wavelength (or frequency) of the mercury lamp but also a few much fainter lines. These are the Raman lines and are caused by the molecule not returning to its original energy state.

It has been shown that the differences in frequency between these Raman lines and that of the exciting radiation correspond to interatomic vibrations within the molecule. They are therefore similar to infra-red absorption frequencies. The two phenomena differ however, in the rules which govern the appearance or non-appearance of certain frequencies. In the infra-red a change in the dipole moment of a molecule is necessary (due to the deformation caused by the vibration) before that particular mode of vibration can be observed. In the Raman Effect a change in the polarizability of the molecule, i.e., a change in the probability of an electron moving from one atom to another, is necessary. The two effects are to a large extent complementary in that each supplies information which the other cannot.

Up to the present Raman spectroscopy has not been applied to any great extent in industrial analysis chiefly because the detection (by means of a photographic plate) of the very feeble radiations involved is a lengthy process involving exposure of up to 70 hours duration. Recently, however,[5] the possibilities of using the method for analysis have been greatly improved by the replacement of the photographic plate by a multiplier photocell device. The use of this type of photocell has not only made it possible to obtain an almost instantaneous measure of the intensity of a given line but also permits the use of recorders to scan wide ranges of wavelength.

The range of analysis which can be made using the Raman Effect corresponds very closely to that from the infra-red with the possible exception of the gases which are much more amenable to infra-red analysis. The chief usefulness of the Raman spectra in analysis would appear to be in the possibilities they offer in conjunction with infra-red techniques in solving those problems which are difficult if not impossible by the latter method alone. In Figs. 8 and 9 are shown Raman spectrograms of some pure hydrocarbons.* These curves are the microphotometer traces from the original photographic plates. In these traces the large peak at the end corresponds to the frequency of the exciting radiation.

Emission Spectroscopy

The term emission spectroscopy is usually reserved for those cases in which

* The numbers inscribed on the peaks are the differences in frequency (wave numbers cm. $^{-1}$) between that of the exciting line and those of the various Raman lines.

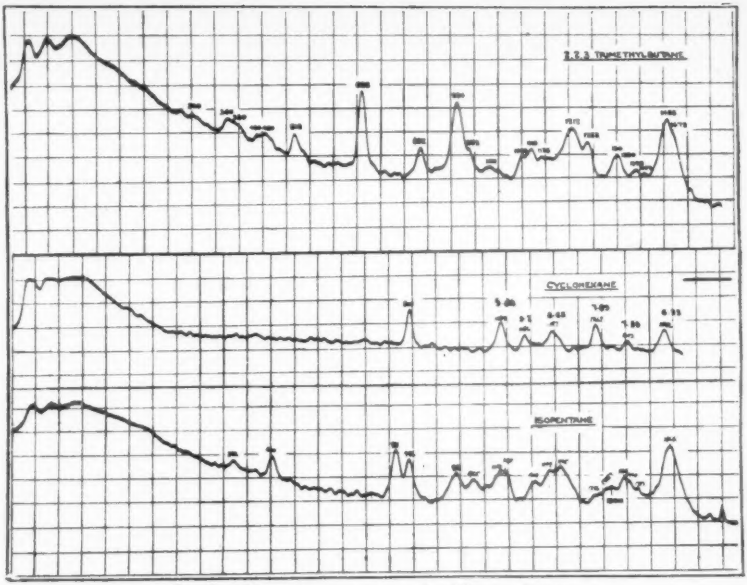

Fig. 8.—Microphotometer records of Raman Spectra

the energy absorbed is supplied violently as in an arc or spark discharge. When this occurs the molecule is broken down into its constituent atoms and the radiations emitted are then characteristic of these atoms and not of the molecule as a whole. In the analysis of metals this method is used to a very large extent but its application to the field of petroleum products is comparatively recent. In this connexion it has two main uses:

(*a*) In the examination of refractory materials such as catalysts;

(*b*) In the determination of the metallic constituents of lubricating oils and additives.

The apparatus used in this work is simpler than that for infra-red spectroscopy and consists of the source of radiation which may be either a D.C. arc, a high-voltage spark or an acetylene flame, a rotating sector disc, a spectrograph of high resolution and dispersion and a microphotometer. The rotating stepped sector disc is a mechanical means of allowing different amounts of radiation to fall on the photographic plate. The steps of the sector vary the total exposures in known ratio, and so allow us to obtain a quantitative calibration between the blackening of a photographic plate and the intensity of light causing the blackening. Once this relationship has been obtained, the blackening of the plate being determined by a microphotometer, it is a simple matter to obtain the intensities of light emitted by the atoms in the sample. The assumption is then made that the intensity of light emitted characteristic of a given atomic species, is proportional to the amount of that particular component in the sample and calibration curves of intensity against concentration of element are constructed by the use of synthetic mixtures.

In practice this simplified procedure has to be modified somewhat owing to

Fig. 9.—Microphotometer records of Raman Spectra

the lack of reproducibility and constancy of arc and sparks sources. The modification made is to add an extra element in known amount and to calibrate the concentration of the element to be determined against the difference in intensities of the characteristic lines of the known and desired elements. This method is known as the "internal standard" method and is almost universally adopted in emission work.

When dealing with refractory powders (e.g., catalysts), which present perhaps the greatest difficulties, the usual practice is to grind the sample in an agate mortar together with ammonium sulphate and the internal standard. The purpose of the ammonium sulphate is to provide diluent free from characteristic emission lines and to assist in the smooth operation of the arc. When dealing with powder samples the D.C. arc is the most commonly used source of energy since the disruptive action of the spark is apt to blow the sample away before it can acquire sufficient energy for emission. In some cases the powdered and mixed sample is briquetted and placed on a hot electrode to which it adheres. The arc is then started and a suitable photographic exposure made. The other method used is to drill a small hole in the top of a metal electrode such as pure copper and then to pack this with the powder, after which the arc is struck. This method of analysis finds its main use as a guide to the more accurate chemical analysis. From the information supplied by the spectrograph as to the elements present, the chemist can plan his analysis to give the required results in the minimum of time.

This is not to imply that spectroscopic emission analysis is always inaccurate. The spectrograph finds its main use as a quantitative analytical tool, however, in those cases where numerous samples all of approximately the same composition have to be analysed for a minor

component and before it can be applied in a similar strictly quantitative manner to the analysis of samples containing a wide range of elements each covering a wide range of concentration, much calibration work remains to be done.

When lubricating oils have to be analysed for their metallic constituents ("additives") a similar procedure to that already described could be followed after the oil has been ashed. This ashing process, however, is cumbersome and lengthy and may be eliminated by the proper choice of a spectroscopic technique.

Two of the most promising methods are:

(*a*) To "atomize" the oil sample, to which an internal standard has been added in the form of an oil-soluble metal salt, into the air stream feeding an acetylene flame. The light emitted by the flame is then separated into its constituent wavelengths by the spectrograph and the determination of the metals carried out as described for catalysts;

(*b*) To absorb the oil sample (with internal standard added) in graphite electrodes by dropping the white hot electrodes into the oil sample. The electrodes can then be used in either an arc or spark discharge as already described.

Both of these methods have their disadvantages, method (*a*) being rather limited by the fact that not all the metallic elements can be detected in this way. Method (*b*) on the other hand requires the use of very pure graphite electrodes which are expensive. Also while in method (*a*) the metals do not have any influence on one another, it is not certain that in method (*b*) they are so independent of one another.

Both methods however eliminate the necessity of a preliminary ashing of the oil sample and since the concentrations of metallic elements likely to be encountered fall within a narrower range more suited to spectroscopic analysis than is the case with catalysts, the results obtained should be of a higher quantitative accuracy.

The Mass Spectrometer

The mass spectrometer has recently been developed in the United States to a very high degree of flexibility and accuracy as an analytical tool. It is usually regarded as a piece of spectroscopic equipment though in principle it is quite different from the spectrometers discussed so far in that it is a mass analyser and has no connexion with the various wavelengths of radiation. It is reputed to perform much the same analytical functions as the infra-red methods of analysis but allows the determination of hydrogen, nitrogen and oygen which cannot be determined by infra-red techniques.

The layout of the apparatus is shown diagrammatically in Fig. 10. The gas or vapour to be analysed is first ionized by electron bombardment in the ionization chamber (A) under high vacuum. The charged particles produced are then accelerated by an electrostatic field (B) before passing into the curved analysing tube (C). A magnetic field is set up perpendicular to the plane of the analysing tube thus causing the charged molecular fragments to move in curves whose radii are proportional to the masses of the fragments. By varying the strength of the magnetic field different masses can be made to pass through the exit slit (D) where they fall on the collector. The current formed by the stream of charged particles is proportional to the number of particles and after amplification is recorded. If the conditions within the apparatus are carefully standardized, then the relative abundances of particles of different masses are characteristic of the original molecule. By plotting the abundances against the masses for a given molecule a result is obtained which resembles a spectrum,

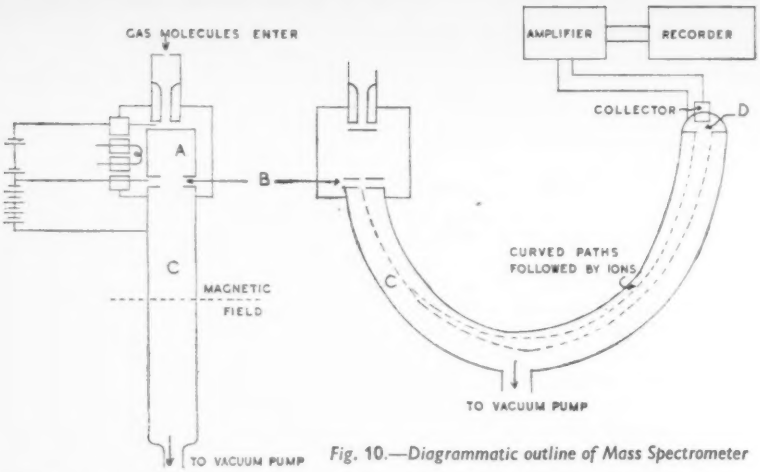

Fig. 10.—Diagrammatic outline of Mass Spectrometer

hence the name applied to this instrument.

The application of the mass spectrometer to analytical work is much the same in principle as that of the other spectroscopic methods discussed. As with the spectrograph it is necessary to calibrate the apparatus using samples of the pure components on which analyses are required. The relative abundances of the different masses characteristic of each molecular type are then treated in much the same way as a series of molecular extinction coefficients at a series of wavelengths to form systems of simultaneous equations whose solutions give the desired analysis.

The mass spectrometer, from what has appeared in the literature, deals with more complex mixtures than either the ultra-violet or the infra-red methods. This leads to a greater complexity in the simultaneous equations since one equation is required for each component and to ease the mechanical labour of computation special electrical computors have been devised. These have been described in the literature and need not be discussed further here.

On the relative merits and demerits of the mass spectrometer compared with say, an infra-red spectrometer for analytical purposes, it is difficult to reach a firm conclusion each having its own advantages. For example time may be saved by the use of a mass spectrometer in eliminating some of the fractionation of samples required before applying infra-red techniques, but on the other hand the initial cost of the mass spectrometer is very high. It is also a very specialized form of equipment and from the purely analytical point of view it may be more profitable to have several infra-red spectrometers rather than one mass spectrometer. On the other hand the mass spectrometer is probably the more accurate instrument especially when it is desired to determine the nature and concentrations of materials known to be present in very small amounts as impurities.

Apart from these analytical considerations however, other information may be obtained by the use of these instruments. For example it has been indicated earlier, that recent developments in infra-red technique now make it a possibility that a wide field of application in reaction kinetics is being opened.

In this respect it may be that the mass spectrometer will also find application though up to the moment the only indication of its possibilities in this direction has been the demonstration of the presence of metastable ions in the analysing tubes.

The infra-red techniques coupled with those of Raman spectroscopy and electron diffraction can give valuable information on molecular structure, which in time may be used in the calculation of certain thermodynamic properties. These subjects are beyond the scope of this paper, however, although it is felt that they should be referred to as distinct possibilities.

REFERENCES

(1) *J. Inst. Petrol.*, 1945, **31**, 428.
(2) *J. Sci. Inst.*, 1945, **22**, 12.
(3) *J. Inst. Petrol.*, 1945, **31**, 191.
(4) Sutherland and Daly. *Nature*, 1946, **157**, 547; Sutherland, Blackwell and Fellgatt, *Nature*, 1946, **157**, 873.
(5) Rank and Wiegand. *J. Opt. Soc. Amer.*, 1946, **36**, 325.

(To be continued)

RECENT DEVELOPMENTS IN MARINE PROPULSION

Summary of an Address by

H. S. HUMPHREYS, M.I.Mar.E., M.I.N.A.

to the Oil Industries Club

IT is proposed to briefly outline the main developments relative to each type of marine propulsion machinery which, either from the points of view of practicability, increased efficiency, or consequent reduced operative cost, have proved themselves worthy of adoption.

STEAM RECIPROCATING ENGINES

First, the steam reciprocating engine. A saving of some 15 to 20 per cent fuel consumption can be made either by introducing a reheater at the high pressure end or an exhaust turbine at the low pressure end of the engine. In the reheater engine poppet valves are used, the steam pressure is about 225 p.s.i. and the total steam temperature 750°F. The superheated steam passes through the tubes of a heat exchanger before being admitted to the h.p. cylinder. To the other side of the tubes of this heat exchanger is admitted the exhaust steam from the h.p. cylinder; resulting in a fall in temperature of the steam to that cylinder to about 600°F, and a rise in the m.p. cylinder to about 550°F, instead of the normal 350°F. By this means the materials and lubrication of the h.p. cylinder are not adversely affected by the increase in superheat, and the efficiency of the m.p. cylinder is increased by the rise in temperature of the h.p. exhaust steam.

There are definite limits to the size and weight of the l.p. cylinder of any reciprocating engine and, therefore, to the steam expansion obtainable.

In the case of the exhaust turbine the l.p. exhaust steam is further expanded and the vacuum in the condenser may reach 29 inches instead of the normal 25 inches in the straight reciprocating engine. The additional power from the exhaust turbine is transmitted to the propeller shafting by means of suitably designed reduction gearing and it is necessary to incorporate a hydraulic coupling in the gearing in order to

neutralize the effect of the uneven torque of the reciprocating engine on the toothed gears.

There are other systems which variously employ the additional power obtained from exhaust turbines. In the Götaverken system, the exhaust turbine drives a turbo steam compressor which is employed to boost up the pressure and temperature of the h.p. engine exhaust steam before admission to the m.p. cylinder. In the Metropolitan-Vickers system the exhaust turbine drives a generator, the current from which is used to drive a motor built directly on to the propeller shafting.

STEAM TURBINES

Then there is steam turbine machinery, with single or double reduction gearing, which enables the efficient high speed of the turbine to be suitably harmonized to the relatively low speed at which propellers prove most efficient. Obviously the bigger the turbine the more efficient it is on account of the reduction in steam losses due to tip clearances of the blades, etc. As an alternative to gearing, turbo electric propulsion with D.C. or A.C. current motors is used. Although there are a few ships sailing with very high pressure boilers the optimum for marine purposes is about 500 p.s.i. with superheated steam at 850°F.

DIESEL ENGINES

There are diesel engines of various types, i.e., 4-stroke single-acting and double-acting, 2-stroke single-acting and double-acting, 2-stroke opposed-piston engines, all of which can directly drive the propeller or be stepped down to an efficient propeller speed by gearing, magnetic slip coupling, or diesel electric drive. The 4-stroke double-acting engine is seldom seen nowadays on account of its being so cumbersome, heavy and difficult to overhaul. It is believed that the Cunard-White Star liner *Georgic*, built in 1932, was the last vessel to be fitted with this type of machinery. All modern diesel engines are of the airless-injection type, which dispenses with the bugbear of a main engine compressor. A further economy in the case of diesel engines is the utilization of the waste heat exhaust gases for maintaining steam in a boiler. It should be noted that whereas in the case of turbine plants the larger the unit the more efficient it is, in the case of diesel machinery the efficiency does not vary much between the small and large engines. Furthermore, the diesel, being a reciprocating engine, the size is governed by the speed of the engine on account of limits to piston speed, inertia forces of the reciprocating parts, etc. Above about 7000 b.h.p. per shaft the direct-drive diesel engine becomes very cumbersome and the steaming weight of machinery becomes much heavier than the turbine of similar power. To compete, therefore, with the turbine in steaming weight of machinery diesel electric or geared diesels must be considered, i.e., faster running and smaller diesel units.

MODERN DEVELOPMENT

Now, what is meant by modern development? How often are the most intricate and ingenious devices added to an engine in order to save a few per cent in fuel, which is swallowed up in the cost and delay incurred by breakdown. The shipowner has to consider an all round balance and from his point of view development means increased reliability, manœuvrability, accessibility with ease of overhaul (and therefore simplicity), and the amount of cargo carried by a given size of ship in a given time. It is a waste of money to instal complicated gadgets in vessels on world trading unless the personnel is educated sufficiently to get the maximum efficiency from them. The machine should not advance too far

beyond the man. Miles from land in all weather conditions an engineer has to rely upon his own resourcefulness in case of breakdown; he has neither engineering works, nor laboratories, nor specialists beside him.

It is interesting to note in the field of competition some of the ingenious methods which have been adopted in various types of machinery. The return to superheat in steam reciprocators; improved valve gears; exhaust turbines; higher pressure water-tube boilers for turbine drive; supercharged or pressure induction 4-stroke single-acting engines by means of under-piston supercharge or exhaust-gas blowers, in order to increase the power of the engine up to 40 per cent and so compete more nearly in weight with the 2-stroke diesel; higher speed geared diesels and so on. In all types of modern machinery fabricated steel is now being used instead of cast iron for bedplates, columns, entablatures, etc, further to reduce the steaming weight. There have of course also been considerable improvements in the design of the ship to obtain the correct form for minimum resistance, with streamlined rudders and more efficient propellers.

Since the beginning of the century the consumption of fuel for marine engines has gone down by 75 per cent, thus, a $\frac{1}{4}$ lb of fuel will now do the work of 1 lb formerly used. The relative fuel consumptions of the present day can be summarized broadly as follows:

	lb. oil/s.h.p./hr.
Standard steam reciprocating engine	1
Reheat steam reciprocator or steam reciprocator with exhaust turbine	0·8
Geared turbine varying according to pressure, temperature and size	0·55 to 0·65
Diesel engine, varying with type	0·34 to 0·38

It might be mentioned that the thermal efficiencies of various types of engines are approximately:

	Per cent
Non-condensing loco	7 to 9
Steam reciprocating Engine, about	16
Turbine	25
Diesel	35 to 40
Gas turbine according to amount of heat exchangers, etc, added	22 to 28 although, on paper, over 30 per cent is now being claimed.

Whilst all these advances have been taking place it is sad to reflect—in view of the fact that coal was previously our greatest national asset—that, whereas a few years ago oil tankers used coal for bunkers, there are now diesel colliers using oil for fuel.

We seem now to be reaching the apex of development with both turbine and diesel machinery. There are limits to which we can go and our thoughts now turn to a new prime mover.

GAS TURBINES

If the gas turbine can obtain reliable materials enabling higher temperatures, say 1500°F, to be used, its use may become more general but at the moment its efficiency is lower than that of the diesel, even with the addition of heat exchangers and other complications. It is lighter but more expensive than the diesel engine. There appears to be a good case for fitting variable pitch (reversible) propellers for gas turbines rather than electric transmission.

It is not impossible that a combination of diesel engine and gas turbine may be designed, utilizing the main engine exhaust gases, and that a fuel consumption much lower than any at present may be obtained.

NUCLEAR ENERGY

The next step may be the use of nuclear energy. It has been said that 1 lb of uranium is equal to 1500 tons of coal, and so the imagination runs to the possibilities of very large powers with relatively small weight of equipment and fuel, although some heavy concrete

insulation may prove the snag in protecting personnel against radio-active radiation.

No less an authority than Sir Amos Ayre, in his recent Presidential Address to the Institute of Marine Engineers, visualized speeds of vessels in which, based on a 36-knot destroyer 330 feet in length, the corresponding speed of a ship 1000 feet in length would be 63 knots. In regard to the economic aspect, however, we do not know how much other fuel would be required to produce it in a form in which it would be taken on board ship, or what the cost of the process would be. The possibility of the application of nuclear energy to gas turbines is a further feature of imagination.

Whatever the future evolution of marine machinery, it is sincerely to be hoped that, as in the past, the British engineer will succeed in more than holding his own in all new developments and the "Red Duster" will be as evident in all waters and all quarters of the globe as was previously the case.

DISCUSSION

THE PRESIDENT (Mr G. H. Coxon): Very few realize the changes which have taken place in the course of the development from the coal-burning to the oil-burning tanker. It must be borne in mind that although the oil companies desired to sell fuel oil, they were also anxious to ensure that matters developed along the most economical lines, so that steamships would operate on the lowest possible oil consumption.

The gas turbine would come, especially when the combustion engineers could provide for the burning of heavier fuel oils. The oil industry was very seriously interested in the use of heavy fuels; but as their use developed, there would be a great shortage of the lighter distillate oils in the world, and if diesel engine manufacturers developed their engines in the hope of obtaining the lighter oils he felt sure there would be a change in the next three or four years.

Asking if there were developments whereby jet propulsion, as applied to aircraft to-day, would be applied to medium-sized ships, he said that if there were it would open up another interesting page in the book of progress, because he understood that the weight of the prime mover in jet-propelled aircraft was so much smaller than with the present engines that they could afford to carry the extra fuel consumption. He understood also that the lower maintenance costs in jet propulsion was a very important factor in the total cost of running an aeroplane. If that were so, the operators could stand a higher fuel consumption, if higher fuel consumption were involved.

MR HUMPHREYS replied that he did not know of any application of jet propulsion to ships other than in the ordinary gas turbine. One could refer to a propeller as a jet; but that was not what the President had meant. Some years ago the hydraulic jet was tried out in very small boats, but he believed the efficiency was so low that the scheme was dropped. However, he personally had had no actual experience of it.

MR NIELS MATHIESON, recalling Mr Humphreys' remarks with regard to poppet valves on the h.p. cylinders of steam engines, asked if trouble had been experienced with the timing gear.

Asking for more information on the magnetic slip coupling, he wondered whether that was D.C. excitation creating eddy currents in an armature.

With regard to the point that, above 7000 s.h.p. per shaft, the direct-drive diesel engine became cumbersome, he asked whether, by the application of the magnetic slip coupling, that position could be improved to a certain extent.

Finally, he asked whether there had been any difficulty in practice with the opposed-piston diesel engine.

MR HUMPHREYS replied that poppet valves were fitted very extensively during the war to the re-heater engine, developed by the North-Eastern Marine organization. His company had managed only one ship so fitted during the war and had experienced no trouble whatsoever with it, either with the valves themselves or with the actuating gear. Obviously, it was a great improvement on the old slide valve.

He had had no actual experience of the magnetic slip coupling, but from what he had heard it was quite good and gave good results.

On the question of the direct-drive diesel engine becoming cumbersome at above 7000 b.h.p. per shaft, he emphasized that the engine itself was only part of the job. An important factor to the shipowner and his pocket was that his ship should be as light as possible, provided it was quite up to A1 standard. It was the steaming weight which affected him, not the weight of the engine itself. One would find that in any engine installation up to 7000 b.h.p. per shaft, whether it be a diesel, a turbine, or a steam reciprocator, the weight of the engine itself would be fairly consistent at about 50 per cent of the steaming weight. For example, in the Doxford engine installation of 3500 b.h.p., the weight of the engine would be 280 tons; the steaming weight, which included the auxiliaries—coolers, propeller shafts, and so forth—would be about 560 tons, i.e., just double the weight of the engine. Again, in the case of a reciprocator of about the same power, probably the main engine would weigh about 375 tons, with boilers, and the steaming weight would be about 750 tons.

The steaming weight also came into the picture in gas turbine installations. We were accustomed to speak of the gas turbine as being light but it was bulky and there were still the auxiliaries, etc, in the engine room; although the gas turbine itself was lighter than other engines, on the basis of steaming weight, the gas turbine installation was not lighter than other installations in the same proportion. The auxiliaries were still necessary for operating a ship, whatever main engines were used.

A modern turbine installation of 7000 s.h.p. was probably about 200 to 250 tons lighter in steaming weight than a diesel engine of the same power; the turbine installation might have a steaming weight of about 900 tons and the direct-drive diesel about 1100 to 1150 tons. As the powers increased above 7000 s.h.p. so the difference in steaming weight would increase in favour of the turbine. In some types of single-screw diesel machinery 8 or even 10 cylinders would need to be considered and there were limits to the power to which we could go with the diesel, whereas 13,000 s.h.p. had been developed on one shaft in the case of turbine machinery. To compete with the turbine—as far as steaming weight of machinery is concerned—one had to consider geared diesels, or diesel electric drive above powers of about 7000 s.h.p., i.e., higher speed and smaller diesel units. The most suitable propeller speed for a 12-knot ship was about 100 r.p.m. but for higher speeds the propeller speed can be raised accordingly.

Finally, dealing with the question concerning the opposed-piston arrangement, Mr. Humphreys said his company had had built more than 50 Doxford opposed-piston engines, and of 29 ships now building 21 were being fitted with Doxford engines. Those built had given comparatively little trouble; there had been no trouble at all with crankshafts, and some of the tankers built in 1937 had not yet had to renew any cylinder liners in the main engines.

PETROLEUM AS A CHEMICAL INDUSTRY

In our January issue a paper by Dr G. Egloff on "Petroleum as a Chemical Industry" was published. When this paper was read at a meeting of the Stanlow Branch on 16 August, 1946, an interesting discussion followed, and the questions of more general interest, with Dr Egloff's replies, are summarized below:

Q.—What is the most widely used process for separating butadiene?

A.—A widely employed method involves the use of copper compounds, such as basic copper acetate, which selectively absorb the butadiene from gas mixtures for later release on controlled heating. Some alkyl acetylene hydrocarbons are also absorbed but these are largely retained and do not contaminate the released butadiene.

Q.—Are these copper compounds used as solids or in solution?

A.—They are used in several ways. In some the reagent is deposited on inert granular material, but in the majority it is used in solution. Many types of plant are used. The trouble at first was that the nature of the impurities in the butadiene was not known. The first batches, although containing about 98·5 per cent of butadiene, gave rise to difficulties in the polymerization reaction with styrene.

Q.—Is there any possibility of synthesizing wearing apparel or food from petroleum?

A.—One thing is clear, edible fats can be made from petroleum—in fact, they are already being made by the oxidation of paraffin wax to fatty acids of, say, 16, 17, 18, carbon atom content. These are then converted to glycerides with glycerine made from propylene, propane or both. The Germans actually made tons of such material and used it as food. It is not a complete substitute for natural fats, because it lacks other essential components present in natural fats.

There is no difficulty with regard to textiles: one can make all kinds of polymerized or oxidized substances such as nylon via acetylene, from which sheer hose for the ladies, materials for shirts, or other useful items for men, may be produced. Undoubtedly we can convert these polymers into materials useful for clothing, but at present they would be uncomfortably hot, because they do not permit the free passage of air. The Germans actually produced light clothing materials from some of the products of butadiene. If and when it is desirable to produce textile materials in quantity, they can be produced from petroleum and natural gas. There are very few organic substances which cannot be synthesized. A new field is open to the organic chemist, since there is a whole series of hydrocarbon raw materials on which no research has yet been done. Then there is a host of substances which can be derived from coal tar, research on which has been going on for over a hundred years.

As an example of the production of base hydrocarbons, one company is thermally cracking cyclohexane derived from petroleum to produce ethylene, butadiene and hydrogen. The ethylene is used to alkylate benzene to produce styrene and this compound is polymerized with varying proportions of butadiene to produce different grades of Buna-"S" rubber.

Q.—What do you consider is the most efficient process for the analysis of hydrocarbons? Is it the spectrograph?

A.—The spectrograph is far ahead of any other analytical tool. The development of the mass spectrograph is of particular interest; installation of the instrument costs $25,000. As an example of its usefulness—a mixture of seventeen gaseous components was submitted to the Consolidated Engineering Company for analysis. The com-

ponents were analysed quite accurately but acetone to the extent of 0·1 per cent was reported as being present. The people who made up the mixture stated, however, that there was no acetone in it. Another sample was made up: the report again came back that acetone was present. Although it was asserted that no acetone was put into the sample, it transpired eventually that the container used for the gas had been washed out with acetone and then dried by air blowing. A mass spectrograph was obtained at once by Universal Oil Products Company and is now being modified to analyse liquid mixtures. The effect of this instrument on laboratory methods is revolutionary. It far surpasses the old laboratory methods of analysis and can do, in one afternoon, work that formerly required six days. To-day the analytical chemist has a far higher standing with his fellow chemists than before.

Q.—Should the organic chemical industry tie in with the petroleum industry and other industries or by so doing would it tend to become relegated to a minor standing?

A.—The Shell Company was one of the earliest to go into the chemical industry and form a separate subsidiary corporation, the Shell Chemical Company. To-day there is a definite trend to tie in petroleum companies with chemical companies. For example the Texas Company and the American Cyanamid Company have joint ownership of a chemical enterprise called the Jefferson Chemical Company. When all get into operation, what grand competition there will be for business, which is only proper and certainly stimulating for the chemists! As far as the United States is concerned, to-day is the hey-day of the chemist because he is so much in demand. His compensation has gone up substantially over what it was pre-war. He has "produced the goods".

Q.—What work is being done on chemicals in the coal carbonization industry?

A.—As our steel industry goes up or down so does the coal carbonizing industry. There is only one large company working on these lines, and it appears that nothing of importance has been brought about by high temperature carbonization of coal, as very little seems to have been published. The oil industry, by comparison, is very free in putting forth its knowledge and experiences. It is very generous in permitting its research men to publish articles and attend scientific and technical meetings.

Q.—It is understood that in the United States it is the policy of large research organizations to spend a certain proportion of their money on the education of junior people. What form does this education take?

A.—It is not known to what extent that is taking place, but those men who want to take the higher degree of M.Sc. or Ph.D. are permitted to do so, and their jobs are kept open for them when they return. In fact, this policy is encouraged: it is felt that those extra two or three years at the university under a suitably qualified professor bring compensation—perhaps as much as three times the salary the man was getting. It is our duty to encourage this arrangement. The higher the degree, the more one is paid. This is good psychologically. The money which is granted to these people is to be used without restrictions: the student is given so free a hand that his company does not even get the first chance of employing him on the completion of his course. Numerous large corporations in the United States are inaugurating fellowships at universities which will permit training of men for later service in industry. What has been done is to take able men from the teaching and research institutes and put them into industry. Fewer qualified and able men

are thus left to teach chemistry, physics, mathematics, and engineering—all extremely important in industry. We have been guilty like other companies and, in the long run, we will lose more than we have gained, so we are now reversing this policy with all our might. However, higher learning is encouraged because it is felt that after three years at a university, particularly if he has had two years in industry, a man of ability will learn far more than if he had taken his degree in the usual manner.

Q.—A lot has been written about the Fischer-Tropsch process. Do you think there is any possibility that in the near future synthetic lubricating oil made by this process will be competing in the economic field with ordinary conventionally refined lubricating oil?

A.—This process makes a good grade of lubricating oil. It is not known how quickly synthetic lubricating oil will be brought on to the market. It may very well be that as the jet-propulsion engines or gas turbines come into being where severe operating conditions are present, we may have to develop some lubricating oils that are non-combustible. How hydrocarbon can be non-combustible is not yet known, but it is not outside the realm of possibility. The Carbide & Carbon Chemical Company in New York State are polymerizing ethylene into lubricating oil. These oils are too dear at the moment, costing 75c a quart—a pretty high price. Their serviceability has not been fully proved as yet.

Q.—Is there a trend toward the development, production and use of high cetane number fuels?

A.—The trade has asked for diesel fuel with cetane number of 100 or higher. The Fischer-Tropsch process can produce 100 cetane number fuel and obviously this is of far better quality than that we have been able to produce from petroleum. As a matter of fact, the installation of Fischer-Tropsch units just for the cetane value obtainable therefrom was considered, but the war stopped the project and the interest has abated. If we can produce at an economic price—70, 80, or 90 cetane number diesel fuels, the engineer will design engines that will make good use of them.

Q.—Is there any commercial future in the use of electric discharges for synthesizing materials from petroleum hydrocarbons on the one hand and oxygen and nitrogen on the other?

A.—Experiments have been carried out in our laboratories with electric discharges—both the silent and the noisy ones—and all kinds of products are being made. One process developed at Texas University produces acetylene from methane, ethane, propane, octanes, good yields of acetylene being obtained on a once-through basis. A number of chemical companies have helped to finance these researches. It is claimed that acetylene could be produced at 2c a pound by passing a silent discharge across a narrow passage through which the gases are fed. From the engineering standpoint, the apparatus could be improved upon, but it is certainly producing acetylene. Professor Lind of Wisconsin, has been able to convert methane/ethane gas mixtures into substances of high molecular weight. The functions of electrical discharge and its destructive qualities have not yet been commercialized so far as it is known. Standard Oil Company of New Jersey has a plant for the production of acetylene from cracked gases, and acetylene is being produced in Germany in the same way.

AUSTRALIAN OIL SEARCH

During the year ended 30 June, 1945, the Government of the Commonwealth of Australia expended £29,879 on the search for oil.

FIRST OVERWATER OIL WELL ON ATLANTIC COAST

M. J. Rathbone, President of the Standard Oil Company of New Jersey, announced recently that a site in Pamlico Sound, off the North Carolina shore, has been selected for the first overwater drilling ever attempted along the Atlantic Coast,

The well will be 17 miles from Manteo, North Carolina, and 32 miles north of historic Hatteras Light. The site is about 3 miles west of Barrier Beach, where the depth of the water is about 5 feet.

The new well, designated as North Carolina Esso No. 2, will get under way with the arrival of a large sinkable barge now under construction. The barge, 207 feet long and 45 feet wide—the average drilling barge is 120 feet—will be flooded with water and sunk to the bottom of the Sound to form a base for the erection of a 162-foot derrick. The barge will be firmly anchored by pilings driven at the four corners to provide a base firm as land for the drilling rig.

Housed on the upper platform with the rig will be a diesel-electric power plant to provide electricity for the motors that will turn the drill bits and provide lights for the round-the-clock operations.

The overwater drilling operation will call upon experience gained by an affiliated company, Creole, which regularly drills in water more than 100 feet deep in Lake Maracaibo, Venezuela.

AMERICAN AWARDS TO BRITISH OIL MEN

The United States Government has recently conferred the following honours upon British Oil men:

Legion of Merit; Degree of Officer

Col. Harold B. Eyles, O.B.E., who, as Chief of Petroleum Section, Allied Force Headquarters, from December 1943 to June 1945, "demonstrated an outstanding ability to organize and control the shattered and demoralized oil industry in Italy. Through meticulous care and infinite patience Colonel Eyles built the Comitato Italiano Petroli into a powerful petroleum operating agency to quickly support the Allied war effort in Italy."

Bronze Star Medal

Lieut.-Col. David Ferrell, Chief of Provision Branch, Petroleum Section, Allied Force H.Q., from January 1943 to August 1945, "was responsible for the complete provisioning of petroleum products into the Mediterranean Theatre of Operations and contributed materially to the success of the operations."

Major John F. Landon, as Chief of Transportation, Petroleum Section, Allied Force H.Q., "was responsible for the complete tanker programme in Italy, and by outstanding initiative and foresight, an efficient programme for the proper scheduling and reception of tankers . . . contributed materially to the uninterrupted and successful flow of petroleum products."

Medal of Freedom with Silver Palm

Sir Andrew Agnew, C.B.E., Hon.F. Inst. Pet., Chairman of the Petroleum Board, from August 1942 to May 1945, "displayed marked leadership, sound knowledge and outstanding ability in expediting necessary petroleum supplies to both the British and American Forces."

Medal of Freedom with Bronze Palm

A. W. Ganley, Engineer Assistant to the Weapons Branch, Petroleum Warfare Department, from May 1944 to May 1945, "rendered invaluable aid to the Allies in developing a mobile mixing plant and training American

crews in the operation of these plants in the production of inert gas."

A. Clifford Hartley, C.B.E., F.Inst. Pet., Technical Director, Petroleum Warfare Department, from January 1943 to May 1945, "displayed foresight, ability and a keen technical mind in improving and perfecting known methods, and in developing new methods of lifting and clearing fog conditions."

A. W. Lawson, O.B.E., Chief Operating Officer of the Petroleum Board, from July 1942 to May 1945, "rendered invaluable aid to the Allies by working ceaselessly and assiduously planning in connexion with the provision of additional storage and distribution facilities of oil products for the British and American Forces, including the pipeline system and arrangements for the supply of petroleum products on the Continent."

P. G. Wickens, Senior Scientific Officer, Petroleum Warfare Department, from July 1942 to May 1945, "displayed exceptional qualities of leadership, wisdom and expert advice, in assisting the American authorities in the development of incendiary fuels."

BRITISH SHALE OIL INDUSTRY

Details of the output of oil shale in Great Britain and of the quantities of crude oil and crude naphtha obtained therefrom show that the annual output of oil shale rose steadily from 1938 until 1942. In the next year there was a slight reduction, followed in 1944 by a decline of 8·5 per cent and in 1945, by a drop of 13·1 per cent, the total for that year being less than in 1938. Production of crude liquid products followed a similar trend, as shown by the official figures* given below, while the calculated average yield per ton of raw material remained fairly constant:

	Oil Shale Production	*Crude oil and crude naphtha from shale*	
Year	*Tons*	*Total output Mill. gal.*	*Average ton Gal.*
1938	1,551,346	32·9	21·2
1939	1,590,821	33·3	20·9
1940	1,597,863	33·1	20·7
1941	1,631,843	34·3	21·0
1942	1,784,247	39·0	21·9
1943	1,759,215	37·9	21·5
1944	1,609,363	35·1	21·8
1945	1,398,202	30·5	21·8

CRUDE OIL PRODUCTION IN GREAT BRITAIN

According to the Ministry of Fuel and Power Statistical Digest, 1945, the production of crude petroleum in Great Britain reached its peak in 1943, with a total output of 29·3 million gallons. First recorded production was in 1939 and details for the six years to 1945 are:

Year	*Production Mill. Gal.*
1939 ..	0·9
1940 ..	4·5
1941 ..	8·0
1942 ..	21·1
1943 ..	29·3
1944 ..	24·5
1945 ..	18·6

PETROLEUM EQUIPMENT AND APPARATUS

Bulletin D recently issued by the Chicago Bridge & Iron Co. describes the Vaporsphere, which is designed to prevent breathing losses from storage tanks equipped with fixed roofs.

Among the latest bulletins issued by the National Supply Export Corporation are No. 315 on the Superior 6G-510 Drilling Engine, No. 318 on the Superior P.T.D. Diesel Drilling Engine, and No. 319 on the Ideal Type "E" Direct Rotary Drive.

* Ministry of Fuel and Power Statistical Digest, 1945.

First post-war catalogue of Robert Jenkins & Co., Ltd., deals with welded tanks and vessels and general engineering plant.

Wire-bound non-rubber hose for petroleum and similar liquids is the subject of a leaflet issued by Hall & Hall, Ltd.

Reprinted from the forthcoming publication of the Council of British Manufacturers of Petroleum Equipment on "British Petroleum Equipment" is the "Classified List of Petroleum Equipment." This publication contains a list of the products of the manufactuers who are members of the Council, classified under various headings, an index to the classified list, and a directory of the members.

Phillips Petroleum Co. has prepared a large-scale vapour pressure chart entitled "Vapour Pressures of Twelve Four-Carbon-Atom Hydrocarbons." The chart, 8 in. by 24 in., shows vapour pressures from 0·30 to 800 p.s.i.abs. over the range—110° to 320° F and includes *iso*butane, *iso*butylene, 1-butene, 1·3-butadiene, n-butane, trans-2-butene, cis-2-butene, vinylacetylene, ethylacetylene, diacetylene, 1·2-butadiene, and dimethylacetylene. Single copies are available free of charge from Phillips Petroleum Co., Chemical Products Dept., Bartlesville, Oklahoma, U.S.A.

Service to industry by Whessoe during the period of reconstruction in Britain and overseas is illustrated in a recent publication issued by Whessoe Ltd.

ARC WELDING COMPETITION

The James F. Lincoln Arc Welding Foundation has recently issued a booklet giving full details of its "Design for Progress" competition for papers or reports on the design or re-design of machines or structures, the operation of a job weldery or maintenance service, or on research or education. Total value of the 452 awards to be gained is $200,000 and the subjects are grouped under 15 main classifications and 43 divisions, which embrace every field of industry and research where arc welding may be applied.

Petroleum machinery and parts is a division of the Industrial Machinery classification and the list of typical subjects is very comprehensive. The competition is open to those who have been engaged in the design, planning or execution of the work or research upon which the subject matter of the paper is based. The competition closes on 1 June, 1947, and full details are available from the Lincoln Electric Co., Ltd., Welwyn Garden City, Herts.

STUDENTS' SECTION (LONDON BRANCH)

At 6 p.m. on Thursday, 13 February, at Manson House, 26, Portland Place, London, W.1., the London Branch of the Students' Section is holding its first post-war meeting. The Speaker will be Lt.-Col. S. J. M. Auld, O.B.E., M.C., D.Sc., a Past-President of the Institute, and his subject will be "Some American Thoughts on To-morrow's Oil." The scope of the address is indicated by the following sub-titles: (i) Re-orientation of sources of raw materials; (ii) Synthesis and substitutes; (iii) Orientation of uses—fuels, lubricants, special products.

Modern Petroleum Technology. A comprehensive picture of the present state of technical knowledge within the petroleum industry. Published by the Institute of Petroleum, 26, Portland Place, London W.1., pp. 466. Price: £1 1s. post free.

The Institute of Petroleum Electrical Code. A suggested Code of Electrical Practice applicable to conditions in the petroleum industry. Published by the Institute of Petroleum, 26, Portland Place, London, W.1., pp. 77. Price: 5s. post free.

CADMAN MEDAL AWARDED TO NOTED AMERICAN SCIENTIST

THE Council of the Institute of Petroleum has expressed its intention of awarding the Cadman Memorial Medal to Mr Robert Price Russell, President of the Standard Oil Development Co., the central technical and research organization of the Standard Oil Company (N.J.).

The Cadman Medal was instituted to commemorate the great services Lord Cadman rendered to the advance of the science of petroleum. The medal is therefore reserved for men who have made outstanding contributions to petroleum technology or hydrocarbon chemistry. Condition of the award is that the recipient shall deliver the Cadman Memorial Lecture, which has to be confined to a related subject. The Lecture this year will be given early in June in the theatre of the Royal Institution, secured through the kindness of the managers—an historic place where many of the world's distinguished scientists have spoken.

Great services were rendered by Mr Russell and his associates during the war in the production of high-octane aviation fuels, synthetic rubbers, and toluene for explosives, and in the development of flame-throwers, incendiaries and smoke generators. More than half the U.S. output of aviation petrol for war-planes was manufactured by the catalytic cracking process, in which Mr Russell played a notable part. Nine-tenths of the American output of petroleum-based butadiene, the starting material in the manufacture of synthetic rubber, came from the process which Mr Russell directed into large-scale production.

Robert P. Russell

In recognition of his war-time work, Mr Russell was awarded the Medal for Merit, the highest civilian award in the United States. The President's citation referred to his "especially meritorious conduct in the performance of outstanding services." He is also holder of the Medal of Freedom and in 1946 was awarded the gold medal of the American Institute of Chemists for "noteworthy and outstanding service to the science of chemistry."

Mr Russell is known personally in Great Britain, for he came here in 1944 as Chairman of the Petroleum, Chemical and Rubber Division of the U.S. Strategic Bombing Survey. A team of scientists under his supervision entered Germany on the heels of the front-line troops to survey the enemy's vast oil-chemical industry. Their work enabled them to make recommendations to improve industrial intelligence, ammunition selection and bombing technique.

Born in Massachusetts in 1898, Mr Russell saw military service in the first World War; subsequently on resuming his studies he obtained a master's degree in chemical engineering at the Massachusetts Institute of Technology in 1923. After holding a number of academic

appointments, he began his distinguished career with the Standard Oil Co. (N.J.), in 1927, when he became research director of the newly established Esso Laboratories at Baton Rouge, La. Here he initiated research in the hydrogenation process and the manufacture of synthetic products from petroleum. At the present time Mr Russell is directing research into new and improved uses for crude oil, into the production of liquid fuels from coal and natural gas, and the development of improved synthetic rubbers and plastics.

COUNCIL COMMENTARY

ONE of Council's duties is to elect the President for each year and it is pleasing to be able to record that Sir Andrew Agnew has accepted Council's invitation to serve for a further year of office.

At the last two meetings of Council various general matters have been dealt with, a new feature being the appointment of a Public Relations Committee; as this includes members of Branches, By-Laws, Publications and Research Committees it should be able to serve a very useful purpose.

Among lighter matters dealt with was the suggestion that a social function should be held in the spring, but after investigation it was decided to defer the holding of such a function until the autumn.

It is of interest to record that the London Branch of the Students' Section has been revived and is at present in active consultation with the Branches Committee in order to overcome certain difficulties which have arisen as a result of National Service. The activities of the Education Committee are also of importance in connexion with the work of the Students' Section. The section has been invited to be represented on the Branches Committee and one of their members is to be co-opted to the Education Committee, which should make for better liaison between the task-masters, who devise, and the students, who have to suffer, examinations in petroleum technology in the future.

It has been decided to hold a Cadman Memorial Lecture this year and, as announced elsewhere in this issue, it will be given by Mr R. P. Russell. Further announcements as to the date and title of the lecture will be made in due course.

The Committee selected for more detailed comment this month is the Abstracts Sub-Committee of the Publications Committee, a review of whose activities has been prepared by the Chairman and from which the following points are selected:

The number of Journals now regularly abstracted amounts to 118, considerably more workers having taken part in preparing half as many extracts again as previously. This had made possible a greater proportion of abstracts dealing with engineering questions, both on the refinery and automotive side.

Until recently patents were merely listed, but short abstracts are now being given.

An important work has been the preparation of detailed instructions for abstractors, which include a list of standard abbreviations of Journal titles (now complete), a list of standard abbreviations of terms for use in abstracts (at present under discussion), and a set of general instructions to abstractors, covering selection of subject matter, method of preparation, nomenclature of chemicals, etc.

The item still being discussed, i.e., the standard abbreviations, affects more than the abstracts as such, it having been

decided that such abbreviations as are decided upon shall be applicable to other publications of the Institute such as "Standard Methods for Testing Petroleum and Its Products", and also that an attempt should be made to get B.S.I. approval for such standard abbreviations for terms used in the petroleum industry. A list of several hundred terms based on B.S.I. procedure or on current usage in the petroleum industry has been prepared and is being considered by the Sub-Committee.

A further step towards unification has been taken by the decision to re-arrange the library under the same headings as are used by the Abstracts Sub-Committee and this classification is also the basis of the revised "Annual Review of Petroleum Technology" for 1946. Thirty out of the thirty-one chapters of this publication have already been arranged for and guiding instructions issued to the authors.

It is proposed to issue a "Quinquennial Review", covering the years 1941-45, and although there have been considerable difficulties inherent in the war and immediate post-war situation, these have now been largely overcome and the majority of the papers are at present in hand, giving good hope that by mid-1947 we shall be able to publish what seems certain to be accepted as a very valuable record of the turbulent years through which we have passed since it was last possible to issue an "Annual Review."

RETIREMENT OF DR. A. E. DUNSTAN

DR A. E. DUNSTAN, who retired from the post of Chief Chemist to the Anglo-Iranian Oil Co. Ltd. on 31 December last after 32 years' service with that Company, is well-known to our readers as Honorary Editor of the Institute's publications from 1921 to 1945.

Dr. A. E. Dunstan

Prior to his joining the then Anglo-Persian Oil Co. Ltd. in 1915 he was head of the Chemical Department of the East Ham Technical College. Soon after his joining the Anglo-Persian he established the research organization at Sunbury-on-Thames and fostered its growth from very modest beginnings to its present position as one of the world's leading petroleum research organizations.

During 1916 Dr Dunstan was sent to Persia in connexion with Admiralty Fuel problems and, in 1917, was made Chief Research Chemist to the Company. In 1926 he became Chief Chemist and in the same year was elected a Director of National Oil Refineries Ltd.

He has been a frequent delegate to conferences in the United States, where he is particularly well-known, and to France. He also served on many scientific and technical committees in

Great Britain, as well as on Departmental Committees such as the main Committee and Chemical Sub-Committee (Chairman) of the Petroleum Warfare Department, and the Fuel Efficiency Committee, the Liquid Fuel Committee (Chairman), and the Creosote-Pitch Committee (Chairman) of the Ministry of Fuel and Power.

Dr Dunstan has always been an active participant in the affairs of the chemical and cognate societies of Britain. He has served on the committees of the Chemical Society and on the Council and Committees of the Society of Chemical Industry, has to his record a long period of uninterrupted service on the Council of the Royal Institute of Chemistry, has been President of the British Association of Chemists, and has given valuable service, to the Chemical Council. His other activities have included Chairmanship of the Technical Education Committee of the Chemical Advisory Board of Education, membership of the Advisory Committee of the Department of Oil Engineering and Refining of the University of Birmingham, and of the Parliamentary and Scientific Committee.

Elected a Member of the Institution of Petroleum Technologists in 1916, he has served on the Council since 1919, and was President from 1929 to 1931. In 1938 he was awarded the Redwood Medal of the Institute and in 1946 the Council awarded him the Honorary Fellowship in recognition of his services to the Institute and of his outstanding contributions to petroleum technology.

His main interest in the Institute has been in its publications and, during his 25 years of Honorary Editorship, the *Journal* and other publications have gained a high reputation in the field of petroleum literature under his wise and able guidance. In this sphere, two of Dr Dunstan's outstanding contributions to the advancement of petroleum technology, are the abstracts of petroleum literature, first started by him in the *Journal* in 1921, and the Institute's "Annual Reviews of Petroleum Technology" which, except for an unavoidable break during the war years, has appeared regularly since 1924.

Members of the Institute and petroleum technologist's throughout the world will join us in wishing him a happy retirement.

PERSONAL NOTES

F. C. Starling, C.B.E., Hon. M.Inst. Pet., who recently retired from the position of Under Secretary in the Ministry of Fuel and Power, was appointed a Companion of the Most Honourable Order of the Bath in the New Year's Honours List.

R. N. B. Brunt, General Manager, Burmah-Shell Oil Storage and Distributing Co. of India, Bombay, was appointed a C.B.E. in the New Year's Honours List.

William Richardson, Executive Secretary of the Petroleum Board's Overseas Supply Committee, was appointed an O.B.E. in the New Year's Honours List.

"For services to the Forces in Burma" the following members of the staff of the Burmah Oil Company have been decorated by H.M. the King: *William Thomas Watts* (O.B.E.), Installation Manager, Chittagong; *Richard George Barnard* (M.B.E.), Chittagong; *John William Imrie* (M.B.E.), Technical Adviser, Calcutta.

The Council of the City and Guilds of London Institute has conferred the distinction of Fellow of the Institute on *C. E. R. Sams*, M.I.Mech.E., F.Inst. Fuel, M.Inst.Pet.

Rear-Admiral Luis de Florez, M.Inst. Pet., has returned to the Presidency of the De Florez Engineering Co. in New York after service in the U.S. Navy as deputy chief of the Office of Naval Research.

M. Fernand Gilabert, who died suddenly in Paris on 21 November, 1946,

had been President of the Societe Générale des Huiles de Pétrole since 1941. He joined the company shortly after World War I and was made managing director in 1939. *Vicomte J. de Rohan*, Vice-President has been appointed to succeed him as President, and *M. Joseph Huré*, Assistant Managing Director, has been appointed Vice-President and Managing Director.

Three new vice-presidents—*William C. Asbury*, *E. Duer Reeves*, and *Dr William J. Sweeney*—have been elected by Standard Oil Development Company to facilitate the Company's expanding research and development programme. *William R. Carlisle*, a vice-president of the Development Co. since 1944, has been appointed associate General Counsel of the Standard Oil Co. (New Jersey) and will remain a Director of the Development Co.

OIL INDUSTRIES' CLUB

The Golfing Society of the Oil Industries Club has arranged a week-end visit to the Dormy House and Golf Course of the Cooden Beach Club, Sussex, from the evening of Friday, April 18, until Sunday, April 20.

Arrangements are also being made for the Club to hold its first post-war Dinner and Dance at Grosvenor House on Friday, April 25.

FORTHCOMING MEETINGS

INSTITUTE MEETINGS

Fuels and Lubricants for Aero Gas Turbines. C. G. Williams. At 26, Portland Place, London, W.1. 5 p.m. Feb. 12.

Modern Developments in Geophysical Prospecting. A. Van Weelden. At 26, Portland Place, London, W.1, 5 p.m. March 12.

NORTHERN BRANCH

Illustrated Dissertation on the Use of Petroleum Additives. A. E. Hope. At Engineers' Club, Albert Sq., Manchester. 6 p.m. Feb. 18.

Annual Dinner and Dance. Midland Hotel, Manchester. Feb. 28.

Progress on the Synthesis of Fuels and Lubricants. Dr. Whalley. At Engineers' Club, Albert Square, Manchester. 6 p.m. March 18.

SCOTTISH BRANCH

Some Impressions of the German Coal Tar Industry. J. Idris Jones. At North British Station Hotel, Edinburgh. 7.30 p.m. Feb. 28.

Engines for Aviation—The Future. F. Rodwell Banks. At Royal Technical College, Glasgow. 7.30 p.m. March 28.

SOUTH WALES BRANCH

Fuels and Lubricants for Aero Gas Turbines. C. G. Williams. At Royal Institution, Swansea. 5.30 p.m. March 14.

STANLOW BRANCH

Fuels and Lubricants for Aero Gas Turbines, C. G. Williams. At Grosvenor Hotel. Ellesmere Port. 7.30 p.m. March 19.

STUDENTS' SECTION (LONDON BRANCH)

Some American Thoughts on To-morrow's Oil. S. J. M. Auld. At 26, Portland Place, London, W.1. 6 p.m. Feb. 13.

MEETINGS OF OTHER SOCIETIES

Production of Oil Fuel. J. S. Jackson, Institute of Marine Engineers (Junior Lecture). At East Ham Technical College, London. 7 p.m. Feb. 27.

Rubber, Natural and Synthetic. S. A. Brazier, M. M. Heywood, G. Martin, W. J. S. Naunton, and J. R. Scott. Society of Chemical Industry. At Institution of Civil Engineers. March 3.

Steam Saving in the Chemical Engineering Industry. A. Milnes. Chemical Engineering Group. At Geological Society, London. 5.30 p.m. March 14.

The Application of Surface Chemistry to Colloidal Problems. Chemical Society (Tilden Lecture). At University College, Nottingham. 7 p.m. March 18.

Combustion Turbines. J. Calderwood. Institute of Marine Engineers (Junior Lecture). At Croydon Polytechnic. 7 p.m. March 18.

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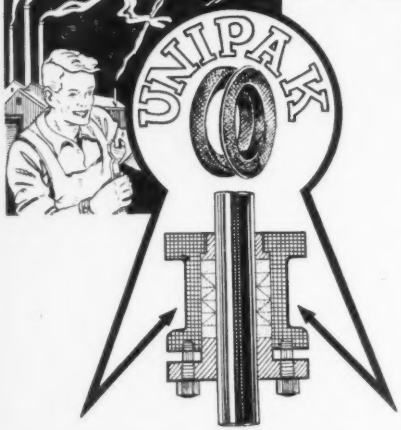

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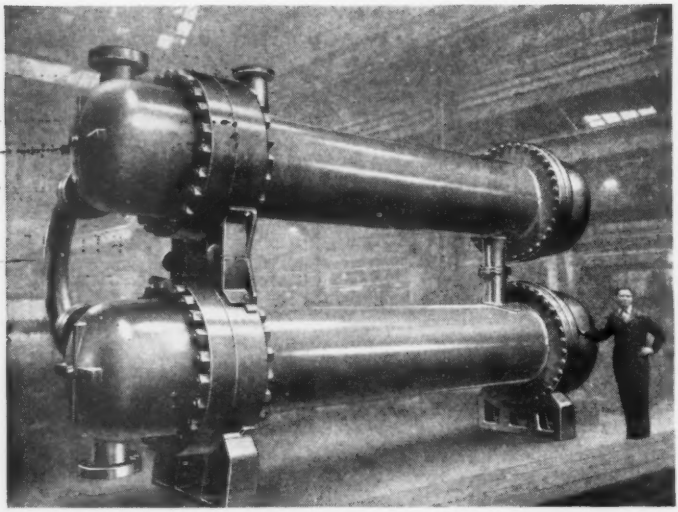

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